SECTION 600.00 – HYDRAULICS

SECTION 610.00 – HYDRAULICS INTRODUCTION

Highway projects that will impact waterways, wetlands, flood plains, etc. have numerous considerations that must be reviewed and approved. An ITD 210, Hydraulics Structures Survey, will be submitted to the Hydraulics Engineer for review for culverts with a diameter of 5 feet or larger, and for all bridges. Additionally, all unusual and complex hydraulic designs such as river modeling, inverted siphons, energy dissipators, storm sewers, detention/retention facilities, pump stations, etc., will also be submitted to the Hydraulics Engineer for review.

Additional hydraulic specifications are in Appendix B. Refer to this data whenever necessary.

610.01 Structure Choice. In order to make an intelligent choice of structure type, all of the questions on the ITD 210, Hydraulic Structures Survey, must be accurately answered. The following hydraulic reports should accompany the ITD 210:

- Structure Field Data
- Hydrologic and Hydraulic Backwater Calculations
- Scour Data and Riprap Requirements
- Comments on Channel Stability
- Permit Status
- FEMA Status

SECTION 615.00 – DESIGN METHODS

Technical hydraulic design information is presented in the *Model Drainage Manual*, S-MDM-3-CD and is available from:

American Association of State Highway and Transportation Officials (AASHTO)

444 N. Capitol St. NW, Suite 249
Washington, DC 20001
1.800.231.3475

The manual was created for counties and highway districts to insert their own policy on various items and then adopt the information as a hydraulic manual. The *Model Drainage Manual* is an excellent technical reference that can be used for most aspects of hydraulic design, but should not be considered as Idaho Transportation Department policy.

A self-taught design manual, Hydrology and Hydraulics, Idaho Transportation Department, January 2002, is available for design guidance in Hydrology, Culverts, Open Channels and Pavement Drainage.

These courses are not considered ITD policy, but are available as references with design examples from the Roadway Design section.

SECTION 620.00 – HYDROLOGY METHODS

The following hydrology methods are approved and listed in the order or reliability.

http://idaho.usgs.gov/PDF/wri024170/regression.pdf

If a USGS Gaging station is close enough to the project to be used, the discharge in cubic feet per second(cfs), based on the period of record for a given recurrence interval in years, and exceedance probability, in percent, can be obtained for most U.S. Geological Survey (USGS) Gaging stations on the internet at http://idaho.usgs.gov/public/h2odata.html . "USGS Magnitude and Frequency of Peak Flows at Gaging Stations in Idaho".

If there is no gaging station nearby, determine if a FEMA Flood Insurance Study (FIS) has been prepared for the river reach of the project. The FIS will have the peak discharges for the 10, 50, 100, and 500 recurrence intervals.

If there is no gaging station or flood insurance study, the USGS Regional Regression Equation Methods should be used. Water Resources Investigations report 02-4170, "Estimating the Magnitude of Peak Flows at Selected Recurrence Intervals for Streams in Idaho", should be used exclusively where possible. Where the use of the Water Resources Investigations report 02-4170 is not possible, at least three methods should be used and either averaged or the maximum value selected for the design flood depending on the closeness of the results of three methods and the preference of the conservancy of the Design Engineer. The following USGS Regression Equation Methods outlined in Appendix B are listed in order of reliability.

Water Resources Investigations report 02-4170, "*Estimating the Magnitude of Peak Flows at Selected Recurrence Intervals for Streams in Idaho*". (Appendix B.40.01) **A computerized application for this publication is currently available on the USGS interactive website,**

Streamstats.wr.usgs.gov/idstreamstats

Open File Report No. 81-909, "*Method of Estimating Flood Frequency Parameters for Streams in Idaho.*" (Appendix B.40.05)

Water Resources Investigation No. 80-32, "*Using Channel Geometry to Estimate Flood Flows at Ungauged Sites in Idaho*." (Appendix B.40.04)

Open File Report No. 93-419 "*Methods for Estimating Magnitude and Frequency of Floods in Southwestern United States*" (Arid Study). Not applicable in Districts 1 & 2.

Water Resources Investigation No. 7-73, "Magnitude and Frequency of Floods in Small Drainage Basins in Idaho," (Appendix B.40.02)

- **Small Area Nomograph.** Can be used for ungauged drainage basins of less than 10 square miles
- **NRCS TR-55 Method.**
- **Rational Method.** Is generally used for storm sewer design and is limited to small watersheds preferably no larger than 200 Acres.

SECTION 625.00 – DESIGN FLOOD

For bridges and culverts 12 feet or more wide, and all culverts that have an open bottom, the design flood will be a 50-year flood. For culverts less than 12 feet wide that have a closed bottom (including those with the invert lowered) the design flood will be a 25-year flood.

625.01 100-Year Flood. 100-year flood data is required for those locations that have been identified by FEMA as flood hazard areas and when the 100-year flood is greater than the overtopping flood, as shown on ITD 210, Hydraulic Structures Survey. The 100-year flood will be determined from the flood Insurance Study (FIS) for the community (City or County) published by the Federal Emergency Management Agency (FEMA).

625.02 Scour Review Flood. The scour review flood will be the overtopping flood or the 500-year flood if the scour review flood is less than the overtopping flood. The 500-year flood can be established by gauge records if sufficient data is available. An approximate value for ungauged basins can be established using U.S. Geological Survey Open File Report No. 81-909.

SECTION 630.00 - PERMITS

The following permits are required for construction projects that will affect stream channels or involve bridges.

630.01 Joint Application for Permit. A stream channel permit is required from the Idaho Department of Water Resources for bridges and other channel work. The Department of Water Resources coordinates the joint application with the Corps of Engineers, the Department of Lands, and the permits are issued by the appropriate agency or agencies. (Refer to Federal Register 33 CFR 320). Instructions for the Joint Application for Permit, IDWR Form 3804-B, are available from the Idaho Department of Water Resources, 332 E Front, P.O. Box 83720, Boise, Idaho 83720-0098.

630.02 Coast Guard Bridge Permit. A Coast Guard bridge permit continues to be required for the improvement or construction of a bridge over waters that are:

- Used as a means to transport interstate or foreign commerce.
- Susceptible to improvement for this use.
- Tidal and used by boats 20 feet or greater in length.

Early coordination during the environmental process is still required.

630.03 Exemptions to Coast Guard Section 9 Permits. Section 123(b) of the *Federal Aid Highway Act of 1987* eliminates the need for Section 9 permits for bridges over certain waters that are not used or not likely to be used in their natural condition or by reasonable improvement as a means to transport interstate or foreign commerce and that are:

- Nontidal, or
- Tidal, but used only by recreational boating, fishing, and other small vessels less than 20 feet in length.

The FHWA Division Administrator has the authority to make the determination of a Section 9 permit. To do this, the District will prepare a statement explaining why the project is exempt from a Section 9 permit using the criteria in Item A. The statement will be attached to the environmental classification summary prepared for the project and submitted to headquarters for processing to FHWA. The District will do the necessary coordination with the Bridge section.

If there are questions regarding the potential for reasonable improvement of the stream, the Army Corps of Engineers should be contacted. The Coast Guard should be contacted if the types of vessels using the waterway are unknown.

SECTION 635.00 – UNUSUAL OR COMPLEX HYDRAULIC DESIGNS

The design of energy dissipaters, detention/retention facilities, pump stations, and all other unusual or complex hydraulic designs will be submitted to the Roadway Design section for the Hydraulic Engineer's approval.

SECTION 638.00 – EMBANKMENT PROTECTORS

Embankment protectors and slotted drains (Standard Drawing D-1-A) function very efficiently with metal guardrail (see Figure 6-1, Example of Determination of Embankment Protector Type). Slotted drains can also be used with concrete guardrail or curb (Standard Drawings D-4-B and D-1-B).

Figure 6-1

Example of Determination of Embankment Protector Type

Given: 3cfs flow and 4% grade. Solution: Find 3cfs flow in the first vertical column of the Length of Slotted Drain or Embankment Protector table below. Proceed horizontally to the intersection with the 4% grade. The intersection yields 50 feet (see the highlighted row and column).

LENGTH OF SLOTTED DRAIN OR EMBANKMENT PROTECTOR							
Flow in cfs	**Grade Percentage**						**Discharge Pipe Size in in.**
	1	**2**	**3**	**4**	**5**	**6**	
1	6	7	8	9	10	10	12
2	8	10	11	12	13	13	12
3	9	12	13	14	15	16	12
4	10	13	15	16	17	18	12
5	12	14	16	18	18	20	12
6	12	15	17	19	20	21	15
7	13	16	18	20	21	23	15
8	14	17	20	21	23	24	15
Cross Slope =0.02 ft./ft.							

From the Dimension Table in Meters for Embankment Protector table below, find the "L" closest to 46 feet. In this case, an "L" of 50 feet with a "D" of 36’ produces a type 4 embankment protector.

DIMENSION TABLE IN FEET FOR EMBANKMENT PROTECTOR		
Type of Embankment Protector	**L**	**D**
1	20	6
2	30	16
3	40	26
4	50	36
5	60	46
6	80	66

SECTION 640.00 – CULVERTS

It is highly recommended the HY-8 computer program be used for culvert design. This is one of the better culvert design software programs available and can be downloaded from the Federal Highway Administration web site. (Include the HY-8 output with your ITD-210/Hydraulic Report submittals)

On all the highway systems, a culvert is a structure having a clear span length between abutments of 20 feet or less, measured along the highway centerline.

The procedure for the design of culverts is discussed in “Drainage Design II Cross Drainage - A Self-Taught Design Course,” published by the Idaho Transportation Department.

Whenever culverts with a diameter equal to or greater than 60 inches are part of the project, an ITD 210, Hydraulic Structures Survey, must be submitted to the Hydraulics Engineer for review.

Other requirements for culverts are as follows:

640.01 Special Pipe Problems. Where a pipe flows at least 3/4 full over a period of a month or more during the year, or pipes are under pressurized flow, then gasketed CMP, rubber gasket concrete, or plastic pipe shall be specified.

Pipe that is on a flat grade may have its capacity lowered simply by being made longer. The size should be reviewed when this occurs.

The condition of the pipe should be carefully studied to be sure the pipe is in good condition. Old pipe in good condition may be left in place and extended on widening projects. Any pipe that will not be used shall be removed, unless prior approval is obtained to fill the pipe with concrete and leave it in place. **Under no circumstances shall any pipe be abandoned that is within the limits of the roadway prism.**

New culvert pipe shall be used on all highway construction. (The average bid price of salvage and removal of existing pipe has proven excessive — to the point that new pipe is more economical. Salvaging structural plate pipe culverts may be considered an exception.) Where pipe culverts are to be removed, enter on the plan only: "Remove Pipe Culvert." This notation is not a separate bid item when shown in this manner and the cost of work is included in the bid price of other items.

Exposed PVC pipe will be protected from ultraviolet radiation by coating, sleeving, or other approved methods.

640.02 Minimum Pipe Size. The minimum pipe diameter shall be 18 inches for pipe culverts under roadways until the culvert length of 70 feet is reached. All culverts over 70 feet long shall be 24 inches or more in diameter. Minimum pipe diameter for culverts under driveways and approach roads and for median drains shall be 12 inches. The minimum diameter of pipe for storm sewers, siphons, and irrigation systems shall be 12

inches. Pipe carrying drainage from irrigated lands shall be considered as culverts and the appropriate minimum size used.

Rubber gasketed concrete pipe arches are not available in Idaho, so the advantage of using concrete arches where clearance is limited cannot be realized. The equivalent size of corrugated metal pipe arches require more cover than round pipe through 30 inches in diameter. The total height from stream bed to road surface is about the same for arch or round pipe in the smaller sizes so round pipe is more economical to use. When an installation requires round pipe of 36 inch diameter or over, the arch pipe will require less total clearance from stream bed to road surface because it provides a shallower, wider passageway. CMP arch pipe may be used to reduce flooding of land upstream from a culvert site. Two other solutions may also be considered (economics is the deciding factor):

1. A larger round pipe may be partially buried below stream bed to provide the same clearance in that opening area as the required arch.
2. A box culvert meeting the conditions may be used.

Pipe arches should normally be limited to sites where headroom is limited. Pipe arches do not necessarily provide better fish passage than round culverts, unless they are embedded to provide a natural stream bed through the culvert. On streams with a wide fluctuation in flow (including most streams), the use of a pipe arch results in a thin layer of flow across a relatively wide invert during low periods of flow. This condition is not conducive to fish passage.

640.03 Clearance for Culverts. Culverts 12 feet or more wide and all culverts with an open bottom shall have a minimum clearance above high water of 1 foot. High Water is defined as the water surface elevation at the inlet of the culvert for the 50-year flood event.

Circular culverts, box culverts, and pipe arches under 12 feet wide that have a closed bottom (including those with the invert lowered) should be designed so that the ratio of the headwater (HW) to diameter (D) during the 25-year flow event is less than or equal to 1.25 (HW/D < 1.25). HW/D ratios larger than 1.25 are permitted, provided that the existing site conditions dictate or warrant a larger ratio. An example of this might be an area with high roadway fills, little stream debris, and no impacted upstream property owners. The justification for exceeding the HW/D ratio of 1.25 must be discussed with the Hydraulics Engineer. The headwater from the 100-year event shall not overtop the roadway and should also be investigated for flooding damage. The culvert must be design so that the 100-year flood can be passed through the culvert without overtopping the roadway.

640.04 Culvert Life. Culvert life for fills greater than 10 feet shall be equal to or greater than the project life unless a cost study shows the total cost including replacement to be less. Project life for the purpose of selecting culvert material shall be as follows:

Interstate	100 years
Primary	80 years
Secondary	50 years

Culvert life for fills **10 feet or less** shall be 50 years.

All PVC pipe will be protected from ultraviolet radiation by either being covered or coated.

640.05 Culvert Alternates. The following alternates shall be accepted as equivalent to each other, subject to the pipe selection table requirements.

- **Side Drains Only**: Corrugated Metal, Concrete Irrigation Pipe, Concrete Bell and Spigot Pipe, or Plastic Pipe.
- **Cross Drains:** Corrugated Metal, Concrete Pipe, or Plastic Pipe.

640.06 Procedure for Selection Culvert Pipe Material. The selection of pipe culverts of 8 feet diameter or less for Idaho highways is to be made in accordance with the following step-by-step procedures. Alternate pipes are to be specified in the pipe summaries wherever several kinds of pipe are found to be satisfactory. Separate designs for the various acceptable alternates are to be made at every installation. If only one kind of pipe is found to be adequate, then only that kind of pipe should be specified.

Step 1. The Joint Materials Report, Phase II - No. 21 Pipe, will list pH and resistivity values for use in pipe materials selection. Limits of pH values for various types of culverts are shown in the Culvert Materials Selection Tables (see Figure 6-2). The estimated life of steel or aluminum culverts can be determined by using the Estimated Life of Steel or Aluminum Culverts, that is (see Section 672.00).

Step 2. Determine the earth and traffic loads to be carried by the pipe. Do not specify any pipe that will not carry these loads. Refer to Pipe Selection Tables, for charts of fill heights above the top of the pipe and loadings that are located (see Section 675.00).

Step 3. Determine whether or not water tightness is required at the pipe installation. If required, specify only those pipes that are acceptable as watertight pipe.

Step 4. Determine the design flood during the life of the project (see Section 625.00). Specify the size of pipe that will carry this flow of water at the culvert site.

Step 5. At each site where pipe is to be used, specify on the pipe summary sheets the various alternates that meet the requirements.

640.07 Specific Pipe Requirements. In addition to the above general procedures, designers are to apply the following specific rules.

Inlet and Outlet Protection

High velocity flow at a culvert outlet will often scour a large hole in the natural channel that results in undermining the culvert barrel and/or roadway embankment. Rigid sectional type pipes placed in erodable soil are vulnerable to disjointing under scour conditions. Most of the **inlet** failures reported by FHWA have occurred on large, metal pipe culverts with projected or mitered entrances without a headwall. Most of the outlet failures have occurred on rigid (concrete) sectional type pipes subjected to scour or erosion washing.

The forces acting on the culvert at both inlet and outlet during flood conditions are variable and compounded by lodged debris. Soils adjacent to the inlet can become saturated and slump into the flood waters, thereby increasing the length of the projected culvert that in turn is subjected to increased buoyant forces. The pipe culvert can then be bent upward by the buoyant force. Mitered or skewed ends on corrugated metal pipe often scour; and erosion beneath the discharge end of rigid sectional pipe results in sections of pipe falling into the channel as the support soil progressively fails.

Attention must be given to evaluation for protection at the ends of culverts. Pipes 48 inches and larger in diameter are more susceptible to inlet or outlet failure than smaller pipe. Inlet protection features should be anchored or designed so that the headwall, slope paving, or riprap will not fall off or slough away from the end of pipe.

Inlets placed on rural sections should be selected to function with the type of guardrail placed on the roadway.

When scour potential at the outlet is great, energy dissipaters or channel design should be designed so that scour is reduced or eliminated.

Headwalls and Bevels for Culverts

All pipe culverts with a concrete headwall and all box culverts shall have their inlet headwalls beveled to improve the inlet flow characteristics. (See Standard Drawings D-2-A, D-7, D-8, and D-9. The only exception to this is if the culvert is flowing under outlet control. Culvert performance is not enhanced by improved inlet conditions when the culvert is flowing under outlet control. It is important however to verify if the culvert remains under outlet control through all ranges of flow under which the culvert will be operating.)

Side Drains

Do not use pipe less than 12 inches in diameter. Do not specify bituminous coatings on corrugated metal pipe for side drains under residential or farm approaches. If side drains pass under commercial or public road approaches, design them as cross drains.

Cross Irrigation and Cross Drains

Cross irrigation pipe shall be designed as watertight. Water tightness for cross drains will be required only if the pipe flows at least 3/4 full for one or more months out of the year. Specify siphon-type corrugated metal pipe or rubber gaskets for concrete pipe cross drains where water tightness is required.

Median Drains

If median drain inlets are protected from debris with grates, use a minimum pipe diameter of 12 inches. If the median drain inlet is not protected with a grate, design the median drain on the same basis that you would if it were a cross drain.

Sewers (Sanitary and Storm)

Generally, concrete or PVC pipe will be used for sanitary sewers. Concrete, PVC, or corrugated polyethelene (PE) pipe will be used for storm drains, unless a special situation would require a different type of pipe. The minimum size for a storm sewer will be 12 inches.

Extensions

If extensions of an existing pipe are required, specify either the same kind of pipe as is already in place or a compatible type.

Pipe Cover

Pipe cover for a flexible pavement is the vertical distance from the outside surface of the pipe crown to the bottom of the flexible pavement at the lowest point. For a rigid pavement, the pipe cover is the distance from the outside surface of the pipe to the finished grade. Ignore the bell when measuring the cover for the bell and spigot pipe. ***Pipes should not be placed in the ballast section.*** Refer to Section 675.00, Pipe Selection Tables for minimum and maximum cover requirements.

SECTION 645.00 – STORM SEWERS

Procedures for designing storm sewers are outlined in FHWA publication “Urban Drainage Design Manual”, Hydraulic Engineering Circular No. 22.

The Hydraulic Grade Line (HGL) will be calculated and documented in the Hydraulics Report and the HGL profile will be shown on the roadway plans. The minimum diameter of pipe for storm sewers, siphons, and irrigation systems shall be 12 inches. Pipe carrying drainage from irrigated lands shall be considered as culverts and the appropriate minimum size used.

Design storm frequency will be in accordance with the table shown below.

RECOMMENDED STORM FREQUENCIES TO BE USED IN DESIGN OF STORM SEWERS	
Design Average Daily Traffic	**Storm Frequency**
Up to 20,000	10 years
20,000 and over, depressed underpasses, and interstate	25 years

Project life for the purpose of selecting storm sewer material will be 100 years. The limits of flooding for a Design Storm will not encroach on the traveled way beyond one-half of the adjacent travel lane.

The design flood for encroachments by through lanes of Interstate highways shall not be less than the flood with a 2 percent chance (50 year flood) of being exceeded in any given year.

The design data for storm sewers (over 24 inches) in diameter will be submitted to the Roadway Design and Environmental sections for review.

SECTION 650.00 – INSTALLATION OF UTILITIES ON NEW BRIDGES

When utility installations are to be incorporated in new bridges, the preferred procedure is to have the required installations and mode of attachment shown on the plans.

When utilities are to be installed on a new bridge, the details of the installations must be furnished to the Bridge section as early as possible.

Adhere to Section 5.8 of the "Utility Accommodation Policy" (GUM-Appendix A) regarding utility installation on structures and coordinate with Utility Engineer for required agreements per the "Guide for Utility Management".

SECTION 655.00 – TIMING OF REQUESTS FOR BRIDGE PLANS AND CHANGES

The District should indicate on an ITD 1414, Project Program Entry or Revision, whenever waterway structures are involved in the project. If waterway structures information was omitted, please notify the Bridge Engineer so that design and detailing can proceed in a routine manner.

Before proceeding with detailed design of a structure, the Bridge Engineer will distribute the layout drawing of that structure to the Maintenance section, the Construction/Materials section, the District in which the structure will be built, and (if

full oversight) to FHWA. Features that are likely to be controversial will be shown or described in the drawing and/or the forwarding letter.

A complete review of the plans should be made at this time to eliminate changes in the structure design after the design is well advanced.

Requests for changes, including addition of one or more structures to a project, may be made on an ITD 1414, Project Program Entry or Revision, or may be in letter form. In either case, the required content is as follows:

- Description of the change desired.
- Justification for the change.
- Estimated increase or decrease in cost resulting from the change.
- Signature and title of person making the request.

SECTION 670.00 – CULVERT MATERIALS SELECTION TABLE

Figure 6-2 should be used when selecting culvert materials.

Figure 6-2

CULVERT MATERIALS SELECTION TABLE

PIPE	pH Value									
	3	4	5	6	7	8	9	10	11	12
Galvanized Steel				X	X	X				
Bituminous-Coated Galvanized Steel*			X	X		X	X	X		
Aluminized Steel			X	X	X	X				
Bituminous-Coated Aluminized Steel*			X	X	X	X	X	X		
Polymer-Coated Steel		X	X	X	X	X	X	X		
(AASHTO M245/M246)										
Aluminum			X	X	X	X				
Bituminous-Coated Aluminum*		X	X	X	X	X	X	X		
Reinforced & Non-Reinforced Concrete			X	X	X	X	X	X	X	X
Plastic		X	X	X	X	X	X	X	X	X

*Use bituminous-coated ONLY when required (increasing metal thickness by one gauge increment is an acceptable substitute for bituminous coating whenever pipe life is 20 years or more).

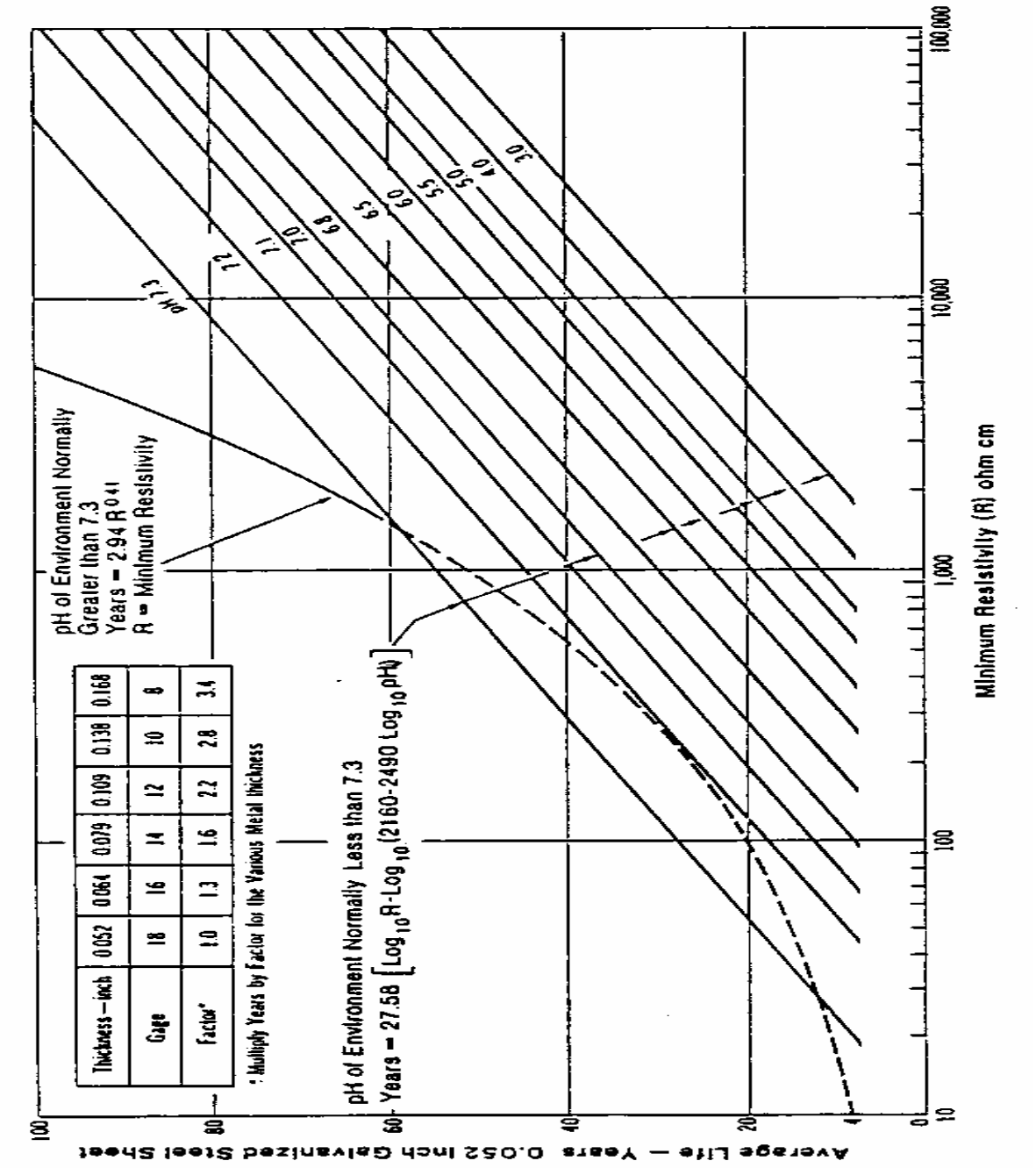
NOTES:

1. The chart covers structural plate, culvert, siphon, irrigation, sewer, embankment protector, and underdrain pipe where applicable.
2. Non-metallic pipe, bituminous-coated aluminum pipe or bituminous-coated aluminized steel pipe shall be used when the soil resistivity is less that 1000 ohm-cm and the pH is above 5.
3. If bed-load velocities of abrasive materials exceed 5 ft/sec, specify 3” x 1” corrugations for steel pipe. Pipes less than 36” exposed to these conditions will have special evaluation.
4. If the bed load velocities of abrasive materials exceed 5 ft/sec aluminum or aluminized steel pipe 60” and larger should not be used. Steel pipe can be used, but its invert should be paved with concrete.
5. Aluminum or aluminized steel CMP must be asphalt-coated where in direct contact with fresh concrete. Special notes in the pipe summary for field coating the concrete-aluminum contract surface may be used in lieu of coating the entire length of pipe.
6. Metallic pipe of unlike materials shall not be joined together. Galvanized steel hook bolts may be used to tie aluminum plate pipe to concrete headwalls.

7. Aluminum pipe shall not be bedded in or backfilled with soils classified as CH or CL. Granular bedding backfill material should be imported.
8. Metal pipe shall not be used in sewer under high type pavement if there are underground utilities that have cathodic protection or if such protection is planned to be installed in the future. For the purpose of this limitation, a high type pavement is defined as Portland cement concrete or plantmix with a 5” plastic pipe (PVC or Polyethelene) is limited in size and fill height, requires protection for culvert ends.
9. All PVC and Polyethelene pipe will be protected from ultraviolet radiation by either being covered or coated.

SECTION 672.00 – ESTIMATED LIFE OF STEEL OR ALUMINUM CULVERTS

Source: "Handbook of Steel Drainage & Highway Construction Products, "American Iron and Steel Institute (1994), page 339. To purchase online www.steel.org, select Shop, Search for Steel Drainage.



SECTION 675.00 – PIPE SELECTION TABLES

The following tables can be used to select appropriate pipe.

CORRUGATED STEEL PIPE 2” x 1/2” x 2-2/3” Annular Corrugations						
Minimum Thickness		0.064” 16 Gage	0.079” 14 Gage	0.109” 12 Gage	0.138” 10 Gage	0.168” Gage
Pipe Diameter	Minimum Cover*	*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement. ***Pipes should not be placed in the ballast section.***				
INCHES		Maximum Fill Heights Above Top of Pipe in Feet				
12	12	92	100+	100+	100+	100+
15	12	74	80	100+	100+	100+
18	12	61	67	86	90	94
24	12	46	50	65	68	71
30	12	37	40	52	54	56
36	12	30	33	43	45	47
42	12	34	47	74	77	81
48	12	30	41	65	68	71
54	12	-	36	57	60	63
60	12	-	-	52	54	57
66	12	-	-	-	49	51
72	12	-	-	-	45	47
78	12	-	-	-	-	43
84	12	-	-	-	-	40
Thickness to 0.168” may be provided where required for abrasion, corrosion, or other factors						

CORRUGATED STEEL PIPE-ARCH
2” x 1/2” or 2-2/3” x 1/2 “ Annular or Helical Corrugations

Pipe Dimensions	Corner Radius	Minimum Cover*	Minimum Thickness	Maximum Fill Heights Above Top of Pipe for Corner Bearing Pressures in Tons/ Square Feet			Round Pipe Equivalent Diameter
Inches	Inches	Inches	Inches/ Ga.	2 Tons	3 Tons	4 Tons	Inches
17 x 13	3-1/2	27	0.064 / 16	13	20	27	15
21 x 15	4-1/8	28	0.064 / 16	13	19	26	18
24 x 18	4-7/8	27	0.064 / 16	13	20	27	21
28 x 20	5-1/2	28	0.064 / 16	13	19	26	24
35 x 24	6-7/8	28	0.064 / 16	13	19	26	30
42 x 29	8-1/4	28	0.064 / 16	13	19	26	36
49 x 33	9-5/8	28	0.079 / 14	13	19	26	42
57 x 38	11	28	0.109 / 12	12	19	25	48
64 x 43	12-3/8	28	0.109 / 12	12	19	25	54
71 x 47	13-3/4	28	0.138 / 10	12	19	25	60
77 x 52	15-1/8	28	0.168 / 8	13	19	26	66
83 x 57	16-1/2	28	0.168 / 8	13	19	26	72

Thickness to 0.168” may be provided where required for abrasion, corrosion, or other factors

Pipes should not be placed in the ballast section.

*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement.

CORRUGATED STEEL PIPE
3” x 1” Annular Corrugations

Minimum Thickness		0.064” 16 Gage	0.079” 14 Gage	0.109” 12 Gage	0.138” 10 Gage	0.168” 8 Gage
Pipe Diameter	Minimum Cover*	*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement. ***Pipes should not be placed in the ballast section.***				
Inches		Maximum Fill Heights Above Top of Pipe in Feet				
36	12	53	66	98	100+	100+
42	12	45	56	84	100+	100+
48	12	39	49	73	88	98
54	12	35	44	65	78	87
60	12	31	39	58	70	78
66	12	28	36	53	64	71
72	12	26	33	49	58	65
78	12	24	30	45	54	60
84	12	22	28	42	50	56
90	12	21	26	39	47	52
96	12	-	24	36	44	49
102	24	-	23	34	41	46
108	24	-	-	32	39	43
114	24	-	-	30	37	41
120	24	-	-	29	35	39

Thickness to 0.168” may be provided where required for abrasion, corrosion, or other factors

CORRUGATED STEEL PIPE-ARCH
3" x 1" Annular or Helical Corrugations

Pipe Dimensions	Corner Radius	Minimum Cover*	Minimum Thickness	Maximum Fill Heights Above Top of Pipe for Corner Bearing Pressures in Tons/Sq. Ft.		
Inches	Inches	Inches	In / Gage	2 Tons	3 Tons	4 Tons
60 x 46	18-3/4	24	0.079 / 14	20	31	39
66 x 51	20-3/4	24	0.079 / 14	20	31	36
73 x 55	22-7/8	24	0.079 / 14	20	31	32
81 x 59	20-7/8	24	0.079 / 14	17	25	29
87 x 63	22-5/8	24	0.079 / 14	17	26	27
95 x 67	24-3/8	24	0.079 / 14	17	25	25
103 x 71	26-1/8	24	0.109 / 12	16	25	33
112 x 75	27-3/4	24	0.109 / 12	16	24	31
117 x 79	29-1/2	24	0.109 / 12	16	25	30
128 x 83	31-1/4	24	0.138 / 10	16	24	32
137 x 87	33	24	0.138 / 10	16	24	30
142 x 91	34-3/4	24	0.168 / 8	16	24	32
Thickness to 0.168" may be provided where required for abrasion, corrosion, or other factors.						

NOTE: Fill heights are invalid if gauge is changed.

Pipes should not be placed in the ballast section.

*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement.

CORRUGATED STEEL PIPE
5” x 1” Annular Corrugations

Minimum Thickness		0.064” 16 Gage	0.079” 14 Gage	0.109” 12 Gage	0.138” 10 Gage	0.168” 8 Gage
Pipe Diameter Inches	Minimum Cover* Inches	Maximum Fill Heights Above Top of Pipe in Feet ***Pipes should not be placed in the ballast section.***				
36	12	53	66	98	100+	100+
42	12	45	56	84	100+	100+
48	12	39	49	73	88	98
54	12	35	44	65	78	87
60	12	31	39	58	70	78
66	12	28	36	53	64	71
72	12	26	33	49	58	65
78	12	24	30	45	54	60
84	12	-	28	42	50	56
90	12	-	26	39	47	52
96	12	-	24	36	44	49
102	24	-	23	34	41	46
108	24	-	-	32	39	43
114	24	-	-	30	37	41
120	24	-	-	29	35	39

*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement.

CORRUGATED STEEL PIPE
2” x 1/2” or 2-2/3” x 1/2” Helical Corrugations

Minimum Thickness		0.064” 16 Gage	0.079” 14 Gage	0.109” 12 Gage	0.138” 10 Gage	0.168” 8 Gage
Pipe Diameter	Minimum Cover*	*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement. ***Pipes should not be placed in the ballast section.***				
Inches	Inches	Maximum Fill Heights Above Top of Pipe in Feet				
12	12	100+	100+	100+	-	-
15	12	100+	100+	100+	-	-
18	12	100+	100+	100+	100+	-
24	12	100+	100+	100+	100+	100+
30	12	85	100+	100+	100+	100+
36	12	71	88	100+	100+	100+
42	12	60	76	100+	100+	100+
48	12	53	66	93	100+	100+
54	12	-	59	82	100+	100+
60	12	-	-	74	95	100+
66	12	-	-	-	87	100+
72	12	-	-	-	79	97
78	12	-	-	-	-	86
84	12	-	-	-	-	75

CORRUGATED STEEL PIPE
3" x 1" Helical Corrugations

Minimum Thickness		0.064" 16 Gage	0.079" 14 Gage	0.109" 12 Gage	0.138" 10 Gage	0.168" 8 Gage
Pipe Diameter	Minimum Cover*	*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement. ***Pipes should not be placed in the ballast section.***				
INCHES		Maximum Fill Heights Above Top of Pipe in Feet				
36	12	81	100+	100+	100+	100+
42	12	69	87	100+	100+	100+
48	12	61	76	100+	100+	100+
54	12	54	68	95	100+	100+
60	12	48	61	85	100+	100+
66	12	44	55	78	100+	100+
72	12	40	51	71	92	100+
78	12	37	47	66	84	100+
84	12	34	43	61	78	96
90	12	32	40	57	73	90
96	12	-	38	53	69	84
102	24	-	36	50	64	79
108	24	-	-	47	61	75
114	24	-	-	45	58	71
120	24	-	-	42	55	67
126	24	-	-	-	52	64
132	24	-	-	-	50	61
138	24	-	-	-	48	58
144	24	-	-	-	-	56
150	24	-	-	-	-	52

NOTE: Fill heights are invalid if gauge is changed.

CORRUGATED STEEL PIPE
5" X 1" Helical Corrugations

Minimum Thickness		0.064" 16 Gage	0.079" 14 Gage	0.109" 12 Gage	0.138" 10 Gage	0.168" 8 Gage
Pipe Diameter	Minimum Cover*	*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement. ***Pipes should not be placed in the ballast section.***				
INCHES		Maximum Fill Heights Above Top of Pipe in Feet				
36	12	72	90	100+	100+	100+
42	12	62	77	100+	100+	100+
48	12	54	68	95	100+	100+
54	12	48	60	84	100+	100+
60	12	43	54	76	98	100+
66	12	39	49	69	89	100+
72	12	36	45	63	81	100+
78	12	33	41	58	75	92
84	12	31	38	54	70	85
90	12	29	36	50	65	80
96	12	-	34	47	61	75
102	24	-	32	44	57	70
108	24	-	-	42	54	66
114	24	-	-	40	51	63
120	24	-	-	38	49	60
126	24	-	-	-	46	57
132	24	-	-	-	44	54
138	24	-	-	-	42	52
144	24	-	-	-	-	50
150	24	-	-	-	-	48

CORRUGATED ALUMINUM PIPE
2" x 1/2" or 2-2/3" x 1/2" Annular Corrugations
Specified in AASHTO M196 or M211

Minimum Thickness		0.060"	0.075"	0.105"	0.135"	0.164"
Pipe Diameter	Minimum Cover*	*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement. ***Pipes should not be placed in the ballast section.***				
INCHES		Maximum Fill Heights Above Top of Pipe in Feet				
12	12	50	50	86	90	93
18	12	33	33	57	60	62
24	12	25	25	43	45	46
30	12	20	20	34	36	37
36	12	16	16	28	30	31
42	12	22	28	50	52	53
48	12	-	25	43	45	47
54	12	-	-	38	40	41
60	12	-	-	-	36	37
66	12	-	-	-	33	34
72	12	-	-	-	-	31

CORRUGATED ALUMINUM PIPE-ARCH
1/4", 7/16" or 1/2" Annular or Helical Corrugations
Specified in AASHTO M196 or M211

Pipe Dimensions	Corner Radius	Minimum Cover*	Minimum Thickness	Maximum Fill Heights Above Top of Pipe			Round Pipe Equivalent Diameter
INCHES	INCHES	INCHES	INCHES	2 TONS	3 TONS	4 TONS	INCHES
17 x 13	3-1/12	18	0.060	13	20	27	15
21 x 15	4-1/8	18	0.060	13	19	26	18
24 x 18	4-7/8	18	0.075	13	20	27	21
28 x 20	5-1/2	18	0.075	13	19	26	24
34 x 24	6-7/8	18	0.105	13	20	26	30
42 x 29	8-1/4	18	0.105	13	19	26	36
49 x 33	9-5/8	18	0.135	13	19	26	42
57 x 38	11	18	0.135	12	19	25	48
64 x 43	12-3/8	18	0.135	12	19	25	54
71 x 47	13-3/4	18	0.164	12	19	25	60

Pipes should not be placed in the ballast section

*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement.

CORRUGATED ALUMINUM PIPE
3" x 1" Annular Corrugations
Specified in AASHTO M196 or M211

Minimum Thickness		0.060"	0.075"	0.105"	0.135"	0.164"
Pipe Diameter	Minimum Cover*	*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement. ***Pipes should not be placed in the ballast section.***				
Inches	Inches	Maximum Fill Heights Above Top of Pipe in Feet				
36	12	30	37	51	77	100
42	12	26	32	44	66	86
48	12	22	28	38	58	75
54	12	20	25	34	51	67
60	12	18	22	31	46	60
66	12	16	20	28	42	55
72	12	15	18	25	38	50
78	12	-	17	23	35	46
84	12	-	-	22	33	43
90	12	-	-	20	31	40
96	12	-	-	19	29	37
102	12	-	-	-	27	35
108	12	-	-	-	25	33
114	12	-	-	-	-	31

CORRUGATED ALUMINUM PIPE
6” x 1” Annular Corrugations Specified in AASHTO M196 or M211

Minimum Thickness		0.060”	0.075”	0.105”	0.135”	0.164”
Pipe Diameter	Minimum Cover*	*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement. ***Pipes should not be placed in the ballast section.***				
Inches	Inches	Maximum Fill Heights Above Top of Pipe in Feet				
36	12	25	32	45	-	-
42	12	22	27	38	-	-
48	12	19	24	33	43	-
54	12	17	21	30	38	-
60	12	15	19	27	34	42
66	12	14	17	24	31	38
72	12	12	16	22	29	35
78	13	-	14	20	26	32
84	13	-	-	19	24	30
90	13	-	-	18	23	28
96	13	-	-	-	21	26
102	13	-	-	-	20	25
108	14	-	-	-	19	23
114	14	-	-	-	-	22
120	15	-	-	-	-	21

CORRUGATED ALUMINUM PIPE 2” x 1/2” or 2-2/3” x 1/2" Helical Corrugations Specified in AASHTO M196 or M211						
Minimum Thickness		0.060”	0.075”	0.105”	0.135”	0.164”
Pipe Diameter	Minimum Cover*	Maximum Fill Heights Above Top of Pipe in Feet ***Pipes should not be placed in the ballast section.***				
Inches	Inches					
12	12	100+	100+	100+	100+	100+
18	12	100+	100+	100+	100+	100+
24	12	77	96	100+	100+	100+
30	12	62	77	100+	100+	100+
36	12	51	64	90	100+	100+
42	12	44	55	77	99	100+
48	12	-	-	66	86	100+
54	12	-	-	54	70	87
60	12	-	-	-	57	71
66	12	-	-	-	-	57
70	12	-	-	-	-	45

*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement.

CORRUGATED ALUMINUM PIPE
3" x 1" Helical Corrugations Specified in AASHTO M196 or M211

Minimum Thickness		0.060"	0.075"	0.105"	0.135"	0.165"
Pipe Diameter	Minimum Cover*	*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement. ***Pipes should not be placed in the ballast section.***				
Inches	Inches	Maximum Fill Heights Above Top of Pipe in Feet				
30	12	71	89	100+	100+	100+
36	12	59	74	100+	100+	100+
42	12	50	63	89	100+	100+
48	12	44	55	78	100+	100+
54	12	39	49	69	92	100+
60	12	35	44	62	83	98
66	12	32	40	56	75	89
72	12	29	37	52	69	81
78	12	-	34	48	63	75
84	12	-	-	44	59	70
90	12	-	-	41	55	65
96	12	-	-	38	51	60
102	12	-	-	-	46	54
108	12	-	-	-	41	49
114	12	-	-	-	-	44
120	12	-	-	-	-	40

* PLASTIC PIPE -- CORRUGATED POLYETHYLENE PIPE – AASHTO M294 & MP-7			
Minimum Cover for Roadway and Public Approaches			Maximum Height of Cover
Size (IN)	Minimum Cover* (FT)		Cover (FT)
12-24	2		15

- All plastic pipe shall be installed to manufacturer's specifications.

CONCRETE PIPE

Type 1 bedding is to be specified on 24" or less pipe, except where fill height calls for Type 3.
Type 2 bedding is to be specified on larger than 24" pipe, unless fill height calls for Type 3.

Minimum Cover* for Roadway and Public Approaches						Maximum Height of Cover		
Size (IN)	Reinforced Concrete Pipe				Class of Pipe	Type 1-2 Bedding	Type 3 Bedding
	II	III	IV	V			
12	2.5	2.0	1.5	1.0	II	Not Used	-
18	2.5	2.0	1.5	1.0	III	10	-
24	2.5	2.0	1.5	1.0	IV	16	-
30	2.5	2.0	1.5	1.0	V	24	35
36	2.5	2.0	1.5	1.0	**DO NOT USE CLASS II CONCRETE PIPE UNDER PUBLIC ROADS**		
Over 36	2.5	2.0	1.5	1.0			

CONCRETE PIPE

Minimum Cover** for Concrete Pipe Under Private Approaches ***Pipes should not be placed in the ballast section.***					Maximum Cover for Irrigation Pipe Under Private Approaches	
Pipe Diameter (in)	Irrigation Pipe (ft)	Class II (ft)	Class III (ft)	Class IV (ft)	Pipe Diameter (in)	Maximum Cover (ft)
12	1.9	1.9	1.4	1.0	12	7.5
15	2.0	1.8	1.2	1.0	15	6.5
18	2.0	1.6	1.0	-	18	6.0
21	2.0	1.6	1.0	-	21	5.5
24	2.0	1.6	1.0	-	24	5.0
30 & Over	2.5	1.5	-	-		

CORRUGATED METAL PIPE UNDER PRIVATE APPROACHES

When corrugated metal pipe is used under private approaches, the minimum cover or H-10 loading may be one(1) foot, provided the following thicknesses are used:

Pipe Diameter	12" – 36"	42" – 48"	54" - 66"	72" – 84"
Minimum Thickness	0.064"	0.079"	0.109"	0.138"

*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement

Minimum cover for rigid pavement over concrete pipe shall include a minimum of 9" of compacted granular fill between the top of the pipe and the bottom of the pavement slab. ***Pipes should not be placed in the ballast section.*

STRUCTURAL PLATE STEEL PIPE
6" x 2" Corrugations Bolted Fabrication

Minimum Thickness		0.109"	0.138"	0.168"	0.188"	0.218"	0.249"	0.280"	0.280", E 1400*	
		4-3/4 inch A-325 Bolts Per Foot of Seam							6 Bolts	8 Bolts
Pipe Diameter	Minimum Cover**	*Excellent backfill, 95% density, E = 1400, K 22. **Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement. ***Pipes should not be placed in the ballast section.***								
FT/IN	IN	Maximum Fill Heights Above Top of Pipe in Feet								
5'- 0"	12	47	68	90	100+	100+	100+	100+	100+	100+
5'-6"	12	43	62	81	94	100+	100+	100+	100+	100+
6'-0"	12	39	57	75	86	100+	100+	100+	100+	100+
6'-6"	12	36	52	69	79	95	100+	100+	100+	100+
7'-0"	12	34	49	64	73	88	100+	100+	100+	100+
7'-6"	12	31	45	60	68	82	97	100+	100+	100+
8'-0"	12	29	43	56	64	77	91	100+	100+	100+
8'-6"	12	28	40	52	60	73	86	94	100+	100+
9'-0"	24	26	38	50	57	69	81	88	100+	100+
9'-6"	24	25	36	47	54	65	77	84	100+	100+
10'-0"	24	23	34	45	51	62	73	80	100+	100+
10'-6"	24	22	32	42	49	59	69	76	95	100+
11'-0"	24	21	31	40	46	56	65	72	90	97
11'-6''	24	20	30	39	44	54	63	69	86	93
12'-0"	24	19	28	37	43	51	61	66	83	89
12'-6"	24	19	27	36	41	49	58	64	80	86
13'-0'	24	18	26	34	39	47	56	61	76	82
13'-6"	24	17	25	33	38	46	54	59	74	79
14'-0"	24	16	24	32	36	44	52	57	71	76
14'-6"	24	15	23	31	35	42	50	55	68	74
15'-0"	24	15	22	30	34	41	48	53	66	71
15'-6"	24	15	22	29	33	40	47	51	64	69
16'-0"	24	-	21	28	32	38	45	50	62	67
16'-6"	36	-	20	27	31	37	44	48	60	65
17'-0"	36	-	20	26	30	36	43	47	58	63
17'-6"	36	-	-	25	29	35	41	45	57	61
18'-0"	36	-	-	25	28	34	41	44	55	59
18'-6"	36	-	-	24	27	33	39	43	54	58
19'-0"	36	-	-	24	27	32	38	42	52	56
19'-6"	36	-	-	-	26	31	37	41	51	55
20'-0"	36	-	-	-	25	31	36	40	50	53
20'-6"	36	-	-	-	-	30	35	39	48	52
21'-0"	36	-	-	-	-	30	34	38	-	51

STRUCTURAL STEEL PIPE-ARCH
6” x 2” Corrugations
Bolted Fabrication

Pipe Dimensions	Corner Radius	Minimum Cover*	Maximum Fill Heights Above Top of Pipe for Corner Pressures of 4000 Lbs/Sq Ft		
Span Rise			Minimum Thickness		
Feet-Inches	Inches	Inches	0.109”	0.138”	0.168”
6’-1 x 4’-7”	18	24	16	16	-
7’-0” x 5’-1”	18	26	14	14	-
7’-11” x 5’-7”	18	29	12	12	-
8’-10” x 6’-1”	18	31	11	11	-
9’-9” x 6’-7”	18	34	10	10	-
10’-11” x 7’-1”	18	36	9	9	-
11’-10” x 7’-7”	18	36	8	8	-
12’-10” x 8’-4”	18	36	7	7	-
14’-1” x 8’-9”	18	36	7	7	-
15’-4” x 9’-3”	18	36	6	6	-
15’-10” x 9’-10”	18	36	6	6	-
16’-7” x 10’-1”	18	36	6	6	-
13’-3” x 9’-4”	31	24	12	12	-
14’-2” x 9’-10”	31	24	12	12	-
15’-4” x 10’-4”	31	24	11	11	-
16’-3” x 10’-10”	31	25	10	10	-
17’-2” x 11’-4”	31	26	10	10	-
18’-1” x 11’-10”	31	28	9	9	-
19’-3” x 12’-4”	31	29	-	8	8
19’-11” x 12’-10”	31	30	-	7	7
20’-7” x 13’-2”	31	31	-	7	7
Thickness 0.168” may be provided where required for abrasion, corrosion, or other factors.					

Pipes should not be placed in the ballast section.

*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement.

STRUCTURAL STEEL PIPE-ARCH
6" x 2" Corrugations
Bolted Fabrication

Pipe Dimensions	Corner Radius	Minimum Cover*	Maximum Fill Heights Above Top of Pipe for Corner Pressures of 6000 Lbs/Sq Ft		
Span Rise			Minimum Thickness		
Feet-Inches	Inches	Inches	0.109"	0.138"	0.168"
6'-1 x 4'-7"	18	24	24	24	-
7'-0" x 5'-1"	18	24	21	21	-
7'-11" x 5'-7"	18	24	18	18	-
8'-10" x 6'-1"	18	24	16	16	-
9'-9" x 6'-7"	18	24	15	15	-
10'-11" x 7'-1"	18	24	13	13	-
11'-10" x 7'-7"	18	24	12	12	-
12'-10" x 8'-4"	18	24	11	11	-
14'-1" x 8'-9"	18	24	10	10	-
15'-4" x 9'-3"	18	24	9	9	-
15'-10" x 9'-10"	18	24	9	9	-
16'-7" x 10'-1"	18	25	9	9	-
13'-3" x 9'-4"	31	24	18	19	19
14'-2" x 9'-10"	31	24	16	18	18
15'-4" x 10'-4"	31	24	15	16	16
16'-3" x 10'-10"	31	25	14	15	15
17'-2" x 11'-4"	31	26	13	15	15
18'-1" x 11'-10"	31	28	13	14	14
19'-3" x 12'-4"	31	29	-	13	13
19'-11" x 12'-10"	31	30	-	12	12
20'-7" x 13'-2"	31	31	-	12	12
Thickness to 0.168" may be provided where required for abrasion, corrosion, or other factors.					

Pipes should not be placed in the ballast section

*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement.

STRUCTURAL STEEL PIPE-ARCH
6" x 2" Corrugations
Bolted Fabrication

Pipe Dimensions	Corner Radius	Minimum Cover*	Maximum Fill Heights Above Top of Pipe for Corner Pressures of 8000 Lbs/Sq Ft		
Span Rise			Minimum Thickness		
Feet-Inches	Inches	Inches	0.109"	0.138"	0.168"
6'-1 x 4'-7"	18	24	32	32	-
7'-0" x 5'-1"	18	24	28	28	-
7'-11" x 5'-7"	18	24	25	25	-
8'-10" x 6'-1"	18	24	22	22	-
9'-9" x 6'-7"	18	24	20	20	-
10'-11" x 7'-1"	18	24	18	18	-
11'-10" x 7'-7"	18	24	16	16	-
12'-10" x 8'-4"	18	24	15	15	-
14'-1" x 8'-9"	18	24	14	14	-
15'-4" x 9'-3"	18	24	13	13	-
15'-10" x 9'-10"	18	24	12	12	-
16'-7" x 10'-1"	18	25	12	12	-
13'-3" x 9'-4"	31	24	18	25	25
14'-2" x 9'-10"	31	24	16	24	24
15'-4" x 10'-4"	31	24	15	22	22
16'-3" x 10'-10"	31	25	14	21	21
17'-2" x 11'-4"	31	26	13	20	20
18'-1" x 11'-10"	31	28	13	19	19
19'-3" x 12'-4"	31	29	-	17	17
19'-11" x 12'-10"	31	30	-	17	17
20'-7" x 13'-2"	31	31	-	16	16

Thickness to 0.168" may be provided where required for abrasion, corrosion, or other factors.

Pipes should not be placed in the ballast section.

*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement.

ALUMINUM STRUCTURAL PLATE PIPE
9" x 2 1/2" Corrugations
Steel Bolts

Minimum Thickness		0.100"	0.125"	0.150"	0.175"	0.200"	0.225"	0.250"
Pipe Diameter	Minimum Cover*							
Inches	Feet	Maximum Fill Heights Above Top of Pipe in Feet						
72	1.25	25	37	50	58	67	77	86
78	1.40	23	35	46	54	62	71	79
84	1.50	22	32	42	50	58	66	73
90	1.50	20	30	40	47	54	57	68
96	1.50	19	28	37	44	50	61	64
102	1.70	18	26	35	41	47	54	60
108	1.75	17	25	33	39	45	51	57
114	1.90	16	23	31	37	42	48	54
120	2.00	15	22	30	35	40	46	51
126	2.00	14	21	28	33	38	44	49
132	2.25	14	20	27	32	37	42	47
138	2.40	13	19	26	30	35	40	44
144	2.50	12	18	25	29	33	38	43
150	2.50	12	18	24	28	32	36	41
156	2.50	-	17	23	27	31	35	39
162	2.70	-	-	22	26	30	34	38
168	2.75	-	-	21	25	29	33	36
174	2.90	-	-	20	24	28	31	35
180	3.00	-	-	-	23	27	30	34

Pipes should not be placed in the ballast section

*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement.

ALUMINUM STRUCTURAL PLATE PIPE-ARCH
6” x 2” Corrugations
Bolted Fabrication

Pipe Dimensions	Corner Radius	Minimum Cover*	Maximum Fill Heights Above Top of Pipe for Corner Pressures of 4000 Lb/Sq Ft						
Span Rise			Minimum Thickness						
Feet-Inches	Inches	Inches	0.100”	0.125”	0.150”	0.175”	0.200”	0.225”	0.250”
6’-7” x 5’-8”	31.8	24	23	26	26	-	-	-	-
8’-1” x 6’-1”	31.8	24	19	21	21	-	-	-	-
9’-7” x 6’-6”	31.8	24	16	18	18	-	-	-	-
11’1” x 7’-0”	31.8	24	14	15	15	-	-	-	-
12’-7” x 7’-5”	31.8	24	12	14	14	-	-	-	-
13’-11” x 8’-5”	31.8	24	11	12	12	-	-	-	-
14’-8” x 9’-8”	31.8	24	-	12	12	-	-	-	-
16’-1” x 10’-4”	31.8	25	-	10	10	-	-	-	-
17’-3” x 11’-0”	31.8	26	-	-	10	10	-	-	-
18’-8” x 11’-8”	31.8	28	-	-	-	9	9	-	-
20’-1” x 12’-3”	31.8	31	-	-	-	-	8	8	-
21’-6” x 12’-11”	31.8	33	-	-	-	-	-	8	8

Pipes should not be placed in the ballast section

*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement.

ALUMINUM STRUCTURAL PLATE PIPE-ARCH
6" x 2" Corrugations
Bolted Fabrications

Pipe Dimensions	Corner Radius	Minimum Cover*	Maximum Fill Heights Above Top of Pipe for Corner Pressures of 8000 Lbs/Sq Ft						
Span Rise			Minimum Thickness						
Feet-Inches	Inches	Inches	0.100	0.125	0.150	0.175	0.200	0.225	0.250
6'-7" x 5'-8"	31.8	24	23	34	45	53	53	-	-
8'-1" x 6'-1"	31.8	24	19	28	37	43	43	-	-
9'-7" x 6'-6"	31.8	24	16	23	31	36	36	-	-
11'-1" x 7'-0"	31.8	24	14	20	27	31	31	-	-
12'-7" x 7'-5"	31.8	24	12	18	23	28	28	-	-
13'-11" x 8'-5"	31.8	24	11	16	21	25	25	-	-
14'-8" x 9'-8"	31.8	24	-	15	20	24	24	-	-
16'-1" x 10'-4"	31.8	25	-	14	18	21	21	-	-
17'-3" x 11'-0"	31.8	26	-	-	17	20	20	-	-
18'-8" x 11'-8"	31.8	28	-	-	-	18	18	-	-
20'-1" x 12'-3"	31.8	31	-	-	-	-	17	17	-
21'-6" x 12'-11"	31.8	33	-	-	-	-	-	16	16

Pipes should not be placed in the ballast section.

*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement.

ALUMINUM STRUCTURAL PLATE PIPE-ARCH
6” x 2” Corrugations
Bolted Fabrication

Pipe Dimensions	Corner Radius	Min Cover*	Maximum Fill Heights Above Top of Pipe for Corner Pressures of 6000 Lbs/Sq Ft						
Span Rise			Minimum Thickness						
Feet-Inches	Inches	Inches	0.100”	0.125”	0.150”	0.175”	0.200”	0.225”	0.250”
6’-7” x 5’-8”	31.8	24	23	34	40	40	-	-	-
8’-1” x 6’-1”	31.8	24	19	28	32	32	-	-	-
9’-7” x 6’-6”	31.8	24	16	23	27	27	-	-	-
11’-1” x 7’-0”	31.8	24	14	20	23	23	-	-	-
12’-7” x 7’-5”	31.8	24	12	18	21	21	-	-	-
13’-11” x 8’-5”	31.8	24	11	16	19	19	-	-	-
14’-8” x 9’-8”	31.8	24	-	15	18	18	-	-	-
16’-1” x 10’-4”	31.8	25	-	14	16	16	-	-	-
17’-3” x 11’-0”	31.8	26	-	-	15	15	-	-	-
18’-8” x 11’-8”	31.8	28	-	-	-	14	14	-	-
20’-1” x 12’-3”	31.8	31	-	-	-	-	13	13	-
21’-6” x 12’-11”	31.8	33	-	-	-	-	-	12	12

Pipes should not be placed in the ballast section.

*Minimum cover is measured from the bottom of flexible pavement and finished grade of rigid pavement.